(1)

OFFICE OF NAVAL RESEARCH

FINAL REPORT

PUBLICATIONS/PATENTS/PRESENTATIONS/HONORS/STUDENT REPORTS

for

Contract N000014-88-K-0360

4R&T Code B41C004DAR01

Thin Film Electrochemical Power Cells

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Part I

a. Complete List of Papers Published in Refereed Journals

K. Naoi, M.M. Lien, W.H. Smyrl, and B.B. Owens, "Capacitive Behavior in Conducting Polymers", Applied Physics Communications, **9**:3 (1989) 147.

M.Z.A. Munshi and B.B. Owens, "Flat Polymer Electrolytes Promise Thin-Film Power", IEEE Spectrum, **26**:8 (1989) 32.

K. Naoi, M.M. Lien, and W.H. Smyrl, "Quartz Crystal Microbalance Analysis: I. Evidence of Anion or Cation Insertion into Electropolymerized Conducting Polymers", J. of Electroanal. Chem. **272** (1989) 273.

K. Naoi, B.B. Owens, T. Osaka and T. Nakajima, "Electroactive Polyaniline Film Deposited from Nonaqueous Media 2: Effect of Acid Concentration in Solutions", The Journal of the Electrochemical Society, **137**:7 (1990) 2139.

M.Z.A. Munshi and B.B. Owens, "Assessment of Thin Film Batteries Based on Polymer Electrolytes: I. Energy Density", Solid State Ionics **38**:1,2 (April 1990) 81.

M.Z.A. Munshi and B.B. Owens, "Assessment of Thin Film Batteries Based on Polymer Electrolytes: II. Pulse Power Density", Solid State Ionics **38**:1,2 (April 1990) 87.

M.Z.A. Munshi and B.B. Owens, "Assessment of Thin Film Batteries Based on Polymer Electrolytes: III. Specific Energy vs. Specific Power", Solid State Ionics, **38**:1,2 (April 1990) 95.

K. Naoi, K.-I. Ueyama, T. Osaka, and W.H. Smyrl, "Impedance Analysis of Ionic Transport in Polypyrrole-Polyazulene Copolymer and Its Charge-Discharge Characterstics", J. Electrochem. Soc. **137**, (1990) 494.

W.H. Smyrl and K. Naoi, "New Monitoring Techniques in Corrosion: Microbalance aand Surface Acoustic Wave (SAW) Devices", in Perspectives on Corrosion, eds. G. Prentice and W.H. Smyrl, AIChE Symposium Series 278, Vol. 86, 1990.

P.S.S. Prasad, M.Z.A. Munshi, B.B. Owens and W.H. Smyl, "Ambient Temperature Solid Polymer Electrolyte Devices", *Solid State Ionics* **40 & 41** (1990).

R. Yang, K. Naoi, D.F. Evans, W.H. Smyrl, and W.A. Hendrickson, "Scanning Tunneling Microscope Study of Electropolymerized Polypyrrole with Polymeric Anion", Langmuir **7**, (1991) 556.

K. Naoi, M. Lien, and W.H. Smyrl, "Quartz Crystal Microbalance Study: Ionic Motion Across Conducting POlymers", J. Electrochem. Soc. **138** (1991) 440.

M. Lien, W.H. Smyrl and M. Morita, "Cation and Anion Insertion in Separate Processes in Poly(pyrrole) Composite Films", *J. Electroanal. Chem.* **309**, 333 (1991).

H.-K. Park, K. Podolske, Z. Munshi, W.H. Smyrl and B.B. Owens, "Quartz Crystal Microbalance and Electrochemical Studies of Li Intercalation in V_6O_{13}", *J. Electrochem. Soc.* **138** 627 (1991).

b. Books and (and sections thereof) Submitted for Publication

none

c. Books (and sections thereof) Published

none

d. Technical Reports Published and Papers Published in Non-Refereed Journals

B. Scrosati, A. Selvaggi, and B.B. Owens, "Rechargeable Lithium Polymer Electrolyte Batteries", Progress in Batteries and Solar Cells, Vol. 8, 1989.

B.B. Owens and P.S.S. Prasad, "The Use of Lithium Batteries in Biomedical Devices", proceedings of the 9th Discussion Meeting of New battery Conceptive Division.

K. Naoi, B.B. Owens, and W.H. Smyrl, "Cell Performance of Ultra-Thin Polymer Cathode Systems: Part I. Anion Intercalating Polymer Cathode", proceedings of symposium on Lithium Batteries, The Electrochemical Society, Hollywood, Florida.

K. Naoi, W.H. Smyrl, and B.B. Owens, "Cell Performance of Ultra-Thin Polymer Cathode Cell Systems: Part II. Cation Intercalating Composite Polymer Cathode", proceedings of symposium on Lithium Batteries, The Electrochemical Society, Hollywood, Florida.

M. Lien and W.H. Smyrl, "An Impedance Study of Polyvinylferrocene Films", in Transient Techniques in Corrosion Science and Engineering, eds. W.H. Smyrl, et al., Electrochemical Society, 1989.

K, Naoi, M.M. Lien and W.H. Smyrl, "Quartz Crystal Microbalance Studies of Electrochemical Growth of Conducting Polymers", Rechargeable Lithium Batteries, (Eds., S. Subbarao, V.R. Koch, B.B. Owens, and W.H. Smyrl, Electrochemical Society, Proceedings Volume 90-5, Pennington, 1990.

T. Osaka, T. Nakajima, K. Shiota, and B.B. Owens, "Rechargeable Lithium/Polymer Cathode Batteries," Rechargeable Lithium Batteries, (Eds., S. Subbarao, V.R. Koch, B.B. Owens, and W.H. Smyrl, Electrochemical Society, Proceedings Volume 90-5, Pennington, 1990.

e. Patents

none

f. Patents Granted

none

g. Invited Presentations at Topical or Scientific/Technical Society Conferences

(1) B.B. Owens, M.Z.A. Munshi, P.S.S. Prasad, W.H. Smyrl, W.K. Jones, J.B. Schlenoff and H.F. Wu, "Performance of Superconductive Oxides as Cathodes for Lithium Rechargeable Batteries", 30th Battery Symposium, Nagoya, Japan, October 10-29, 1989.

(2) B.B. Owens, M.Z.A. Munshi, and P.S.S. Prasad "Application of Polymer Electrolytes to Lithium Batteries", 30th Battery Symposium, Nagoya, Japan, October 10-29, 1989.

h. Contributed Presentations at Topical or Scientific/Technical Society Conferences

(1) L. Atanasoska, K. Naoi, and W.H. Smyrl, "XPS Studies of Doped Polypyrrole Films", 177th meeting of the Electrochemical Society, May 1990.

(2) M.M. Lien, K. Naoi, and W.H. Smyrl, "Quartz Crystal Microbalance Studies: Solvent Effects in Conducting Polymer Films", 177th meeting of the Electrochemical Society, May 1990.

(3) A. Firou[illegible], K. Naoi and W.H. Smyrl, "Morphology Changes due to Oxidative Treatment of Glassy Carbon Electrodes and Its Applications", 177th meeting of the Electrochemical Society, May 1990.

(4) M.M. Lien, Z. Deng, K. Naoi, and W.H. Smyrl, "Evaluation of Ion Intercalation in Conducting Polymers," 177th meeting of the Electrochemical Society, May 1990.

(5) K. Naoi, W.H. Smyrl, B.B. Owens & M.M. Lien, "Capacitive Behavior in Conducting Polymers: AC Impedance and Quartz Crystal Microbalance Studies," 175th meeting of the Electrochemical Society, Los Angeles, California, 1989.

(6) B. Scrosati, B. Selvaggi, B.B. Owens, & M.Z.A. Munshi, "Lithium Polymer Electrolyte Battery, Electrochemical Behavior of Cathode Materials,", 176th meeting of the Electrochemical Society, Hollywood, Florida, 1989.

(7) B.B. Owens, "The Use of Lithium Batteries in Biomedical Devices," extended abstracts, The 40th meeting of the International Societyof Electrochemistry, Kyoto Japan, September 1989.

(8) B.B. Owens & P.S.S. Prasad, "The Use of Lithium Batteries in Biomedical Devices," f the 9th Discussion Meeting of New Battery Conceptive Division, Kyoto, Japan, September 1989.

(9) B.B. Owens, M.Z.A. Munshi, P.S.S. Prasad, W.H. Smyrl, W.K. Jones, J.B. Schlenoff & H.F. Wu, "Performance of Superconductive Oxides as Cathodes for Lithium Rechargeable Batteries," 30th Battery Symposium October 10-29, 1989.

(10) B.B. Owens, M.Z.A. Munshi, & P.S.S. Prasad, "Application of Polymer Electrolytes to Lithium Batteries," Application of Polymer Electrolytes to Lithium Batteries

(11) L.A. Atanasoska, K. Naoi, & W.H. Smyrl, "XPS Studies of Doped Polypyrrole Films" 177th meeting of the Electrochemical Society, May 1990.

(12) M.M. Lien, K. Naoi, & W.H. Smyrl, "Quartz Crystal Microbalance Studies: Solvent Effects in Conducting Polymer Films," 177th meeting of the Electrochemical Society, May 1990.

(13) A. Firouzi, K. Naoi & W.H. Smyrl, "Morphology Changes due to Oxidative Treatment of Glassy Carbon Electrodes and Its Applications," 177th meeting of the Electrochemical Society, May 1990.

(14) M.M. Lien, Z. Deng, K. Naoi & W.H. Smyrl, "Evaluation of Ion Intercalation in Conducting Polymers," 177th meeting of the Electrochemical Society, May 1990.

(15) K. Naoi & W.H. Smyrl, "Quartz Crystal Microbalance Analysis: Partial Cation Release During Oxidation of Conducting Polymers, " 177th meeting of the Electrochemical Society, May 1990.

(16) P.S.S. Prasad, B.B. Owens & W.H. Smyrl, "Interfacial Stability of Lithium in Nonaqueous Gel Polymer Electrolyte Cells," 178th meeting of the Electrochemical Society, October 1990.

(17) M.M. Lien, H.-K. Park, & W.H. Smyrl, "QCM and Impedance Analysis of Polypyrrole," 178th meeting of the Electrochemical Society, October 1990.

i. Honors/Awards/Prizes

none

j. Number of Graduate Students Receiving Degree with Full or Partial Support on ONR Contract

Mary M. Lien, PhD (Chemical Engineering), June 1991

k. Number of Postdoctoral Fellows Receiving Full or Partial Support on ONR Contract

four

Part II.

a. Principal Investigator

William H. Smyrl/Boone B. Owens

b. Cognizant ONR Scientific Officer

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d. Brief Description of Project

Fundamental properties of research cells were correlated with the projected performance of full scale power sources, considering both battery and supercapacitor concepts. In addition to establishing the data base for modelling and performance projections, the program had the additional objective of identifying loss mechanisms and degradation reactions, especially those unique to polymer thin film cell designs. Because of the intrinsic high electrode/electrolyte interface areas, interfacial reactions must be understood. Many applications require power under extreme conditions, and low temperature performance needs to be improved.

e. Graduate Students/Postdoctorals Associates Who were Supported on Project

1. Mary Lien
2. Heai-Ku Park (10% effort)
3. Dr. S. Prasad
4. Dr. M.Z.A. Munshi
5. Dr. A. Selvaggi
6. Dr. K. Naoi

g. Cumulative List of Technical Reports Submitted to ONR

Report #	Title	Authors	Date
1	Capacitive Behavior in Conducting Polymers: AC Impedance and Quartz Crystal Microbalance Studies	K. Naoi, W.H. Smyrl, B.B. Owens & M.M. Lien	6/15/89
2	Lithium Polymer Electrolyte Battery, Electrochemical Behavior of Cathode Materials	B. Scrosati, B. Selvaggi, B.B. Owens, & M.Z.A. Munshi	6/15/89
3	Cell Performance of Ultra-Thin Polymer Cathode System: Theoretical Energy and Power Density Projections	K. Naoi, B.B. Owens & W.H. Smyrl	6/15/89
4	Electrolyte Dependence Dependence of Charge Injection Processes for Electroactive Polymer Films	M.M. Lien, K. Naoi, & W.H. Smyrl	6/15/89
5	Quartz Crystal Microbalance Studies of Electrochemical Growth of Conducting Polymers	K. Naoi, M.M. Lien & W.H. Smyrl	6/15/89
6	Rechargeable Lithium/Polymer Cathode Batteries	T. Osaka, T. Nakajima, K. Shiota & B.B. Owens	6/15/89
7	Impedance Analysis of Ionic Transport in Polypyrrole-Polyazulene Copolymer and Its Charge-Discharge Characteristics	K. Naoi, K. Ueyama, T.A. Osaka, & W.H. Smyrl	6/15/89
8	The Use of Lithium Batteries in Biomedical Devices	B.B. Owens	6/15/89
9	Capacitive Behavior in Conducting Polymers	K. Naoi, M.M. Lien, W.H. Smyrl, & B.B. Owens	6/15/89
10	Rechargeable Lithium Polymer Electrolyte Batteries	B. Scrosati, A. Selvaggi, & B.B. Owens	6/15/89
11	Electroactive Polyaniline Film Deposited from Nonaqueous Media 2: Effect of Acid Concentration in Solutions	K. Naoi, B.B. Owens, T. Osaka & T. Nakajima	6/15/89
12	Flat Polymer Electrolytes Promise Thin-Film Power	M.Z.A. Munshi & B.B. Owens	6/15/89
13	Quartz Crystal Microbalance Analysis: I. Evidence of Anion or Cation Insertion into Electropolymerized Conducting Polymers	K. Naoi, M.M. Lien & W.H. Smyrl	6/15/89
14	The Use of Lithium Batteries in Biomedical Devices	B.B. Owens & P.S.S. Prasad	6/15/89
15	Assessment of Thin Film Batteries Based on Polymer Electrolytes: I. Energy Density	M.Z.A. Munshi & B.B. Owens	9/15/89
16	Assessment of Thin Film Batteries Based on Polymer Electrolytes: II. Pulse Power Density	M.Z.A. Munshi & B.B. Owens	9/15/89
17	Assessment of Thin Film Batteries Based on Polymer Electrolytes: III. Specific Energy vs Specific Power	M.Z.A. Munshi & B.B. Owens	9/15/89

18	Performance of Superconductive Oxides as Cathodes for Lithium Rechargeable Batteries	B.B. Owens, M.Z.A. Munshi, P.S.S. Prasad, W.H. Smyrl, W.K. Jones, J.B. Schlenoff & H.F. Wu	10/23/89
19	Application of Polymer Electrolytes to Lithium Batteries	B.B. Owens, M.Z.A. Munshi, & P.S.S. Prasad	10/23/89
20	Cell Performance of Ultra-Thin Polymer Cathode Systems: Part I. Anion Intercalating Polymer Cathode	K. Naoi, B.B. Owens, & W.H. Smyrl	11/1/89
21	XPS Studies of Doped Polypyrrole Films	L.A. Atanasoska, K. Naoi, & W.H. Smyrl	1/15/90
22	Quartz Crystal Microbalance Studies: Solvent Effects in Conducting Polymer Films	M.M. Lien, K. Naoi, & W.H. Smyrl	1/25/90
23	Morphology Changes due to Oxidative Treatment of Glassy Carbon Electrodes and Its Applications	A. Firouzi, K. Naoi & W.H. Smyrl	1/25/90
24	Evaluation of Ion Intercalation in Conducting Polymers	M.M. Lien, Z. Deng, K. Naoi & W.H. Smyrl	1/25/90
25	Ce': Performance of Ultra-Thin Polymer Cathode Cell Systems: Part II. Cation Intercalating Composite Polymer Cathode	K. Naoi, W.H. Smyrl, & B.B. Owens	3/15/90
26	Quartz Crystal Microbalance Study: Ionic Motion Across Conducting Polymers	K. Naoi, M. Lien & W.H. Smyrl	3/15/90
27	Quartz Crystal Microbalance Analysis: Partial Cation Release During Oxidation of Conducting Polymers	K. Naoi & W.H. Smyrl	3/15/90
28	Interfacial Stability of Lithium in Nonaqueous Gel Polymer Electrolyte Cells	P.S.S. Prasad, B.B. Owens & W.H. Smyrl	5/1/90
29	QCM and Impedance Analysis of Polypyrrole	M.M. Lien, H.-K. Park, & W.H. Smyrl	5/1/90
30	QCM and Electrochemical Studies of Li and Zn Intercalation in V_6O_{13}	H.-K. Park, K. Podolske, M.Z.A. Munshi, W.H. Smyrl, and B.B. Owens	5/1/90
31	Ambient Temperature Solid Polymer Electrolyte Devices	P.S.S. Prasad, M.Z.A. Munshi, B.B. Owens, and W.H. Smyrl	5/1/90